**KWAME NKRUMAH UNIVERSTY OF SCIENCE AND TECHNOLOGY**

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# EFFECT OF GIBBERELLINS ($GA_3$) ON THE POSTHARVEST LIFE AND QUALITY OF PAPAYA FRUITS UNDER AMBIENT STORAGE CONDITIONS

**BY**

**DARI MOSES**

**SEPTEMBER, 2016**

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**A THESIS SUBMITED TO THE SCHOOL OF RESEARCH AND GRDUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL. POSTHARVEST TECHNOLOGY) DEGREE**


**SEPTEMBER, 2016**

## DECLARATION

I hereby declare that the work herein presented is the outcome of my own findings, except for literature reference which I have duly acknowledged, this thesis has not been presented neither in part nor whole for any other degree anywhere.

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## DEDICATION

This thesis is dedicated firstly to the almighty God. Secondly to my lovely wife, Mrs. Dorcas Dari and daughter Yidore Dari for their support and prayers during this course of study.

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# ABSTRACT

Papaya is an important fruit crop in the tropics. The crop however, has a short shelf-life leading to high postharvest losses in papaya growing areas in the Akuapim South Municipality. The study was in two phases including survey and laboratory analysis. The survey was conducted on famers in the Akuapim South Municipality in order to identify the challenges they encounter during papaya production. Majority of the famers mentioned short shelf-life as the main problem they encounter during papaya production even though they have other challenges in the production of papaya fruits in the study area. The research attempted to mitigate this problem by applying a postharvest technology as a way of prolonging the shelf-life of the crop. The laboratory work was carried out at the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST) to determine the effect of $GA_3$ on the postharvest life and quality of papaya fruits under ambient storage conditions in a 2 × 4 factorial arrangement in completely randomized design with three replications. Four rates of $GA_3$ were applied on the papaya fruits at 0mg/litre, 100mg/litre, 200mg/litre and 300mg/litre. It was observed that of all the nine quality characteristics, effect of papaya varieties (colur, shelf-life, weight loss, moisture content and total soluble solids) were significantly different ($p$=0.01). However, effect of variety on pH, firmness, total titratable acidity and sugar/acid ratio did not show significant differences ($p$>0.01). Shelf-life of papaya varieties were significantly different ($p$=0.01). Kapoho had a mean of 11 days to ripen whilst Sunrise recorded a mean of 10 days to ripen. The four $GA_3$ concentrations recorded significant differences on all the nine properties of the papaya fruits. Papaya fruits stored longer as the concentration were increased. Gibberellins concentrations at 0mg/litre had the least mean number of 6 days to ripening whilst the papaya fruits treated with the highest concentration of 300mg/litre had the highest mean number of 15 days. Also, sensory attributes of papaya fruits were highly accepted by the ten (10) panelists. Fresh papaya fruits (control) were served jointly with the gibberellins treated papaya fruits after the storage period to the panelists for their assessment and evaluation. Significant differences ($p$=0.01) were observed for pulp colour, aroma, taste, mouth feel and general acceptability. There was no significant difference (p>0.01) between the control and the gibberellins concentration of 300mg/litre. Overall, papaya fruits applied with gibberellins concentration of 300mg/litre was effective in prolonging the shelf-life of both types of papaya under ambient storage conditions.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Papaya (*Carica papaya*) belongs to the family *Caricaceae*. It is a native of tropical America and has spread all over the tropical and warmer subtropical parts of the world. It is a smaller unbranched soft-wooded tree with latex vessels throughout the plant. Papaya is grown mainly for fresh consumption or for production of the proteolytic enzyme papain from the fruit latex (Salunkhe and Kadam, 1995). The papaya plant is usually dioecious with either male or female flowers. However, hermaphrodite (bisexual) trees also occur. Like many other climacteric fruits, papaya has a short postharvest life. According to Salunkhe and Desai (1984), the postharvest loss of fresh papaya has been estimated to vary from 40-100% under varying climacteric conditions.

Papaya has several industrial uses. Biochemically, the leaves and fruits produce several proteins and alkaloids with important pharmaceutical and industrial applications (E1 Moussaoui *et al.,* 2001).

Currently, Ghana is the world's fourth largest exporter of papaya to the European market but second to Cote D'voire in West Africa. Since Ghana has 3% of the 53 million euro of the EU papaya market the country can increase the production for more market shares (Ghana Export Promotion Council, 2000).

In spite of the health and export potentials of papaya, the production of the crop has several challenges from planting, harvesting and handling of papaya fruits. Postharvest losses in papaya could be as high as 50% which therefore reduces the income of producers and marketers which is a source of livelihood to them (Appert, 1987). This is due to the fact that majority of papaya farmers in the country do not have adequate knowledge in postharvest technology to apply in order to extend the shelf life of this perishable crop. Despite these postharvest losses, little attempt has been made to research on postharvest handling of perishable produce (Tadesse 1991). As a result of papaya fruits being wasted at the farm gate and in the market, many farmers are discouraged from producing and marketing fresh produce and thus limit the consumption of fresh fruits and vegetables by urban dwellers. This therefore threatens the growth and sustainability of the papaya industry. Postharvest losses reduction requires knowledge of postharvest physiology, its applied technical aspect, handling, and the appreciation of its biological and storage potential (Nakasone and Paull, 1998). With this as the situation, there is the need to employ and apply appropriate technologies including the use of $GA_3$ to reduce these postharvest losses of papaya fruits after harvest.

Postharvest dipping of papaya fruits in aqueous solution of $GA_3$ for instance was reported to delay colour and aroma development, retard chlorophyll degradation, ascorbic acid decrease and the decline in the activity of amylase and peroxidase (Vendrell and Palomer, 1997). This study therefore sought to increase the shelf-life of papaya fruits with an appropriate technology in order to satisfy the food as well as the nutritional needs of consumers. It is against this background that the growth Regulator, gibberellic acid ($GA_3$) has been selected for application on papaya fruits. The research, therefore, sought to determine the effect of $GA_3$ on the post-harvest life and quality of papaya fruits under ambient storage conditions.

Specifically, this research sought to determine the:

1. Challenges farmers encounter in papaya production.
2. Effect of $GA_3$ on the physical and chemical characteristics of papaya varieties.
3. Effect of $GA_3$ on the shelf-life of papaya varieties.
4. Effect of $GA_3$ on sensory attributes of papaya varieties.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 ORIGIN AND DISTRIBUTION OF PAPAYA

Papaya (Carica papaya L) is a native to Central America and Southern Mexico through the Andes of South America. It belongs to the family Caricaceae with related species as *Carica stipulate*, *Caricapentagona* and *Caricapubescens*.

A small industry emerged in Florida in the first part of 20$^{th}$ century but declined rapidly with the introduction of viral diseases (Maxwell *et al*., 1984). Historically, in the 15$^{th}$ century, the seeds of papaya were transported to West Indies, Philippines, Africa and Indo-Pak subcontinent before the 17$^{th}$ century.

Papaya prefers good climate for proper growth and development. It must have adequate or optimum temperature throughout the year for good yield (Maxwell *et al.,* 1984). A short exposure to $0^{O}C$ can injure or kills the plant as well as prolong cold. Papaya can thrive well in areas with good wind if well rooted.

Excessive cool temperatures alter fruit flavor. The papaya plant will continue to bear fruits for years but reduces as the plant ages and thus harvesting becomes a problem. On large scale production, fields are replanted after fallowing for about 4-5 years.

Papaya makes excellent container and specimen where soil water and temperature can be optimum. It is grown in India, Peru, China, Indonesia, Venezuela, Jamaica, Brazil and many African countries. In the State, Hawaii is the main producer and distributor of the fruit, with 2500 acres in 1989. It is also projected that there were 350 acres of papaya cultivated in Dade County, Florida in 1987-1988 (Statistics of Hawaiian Agriculture, 1991).

## 2.2 PESTS AND DISEASES OF PAPAYA

Several pests and diseases attack papaya. Singh (1990) asserted that among the 39 arthropods that infest papaya, 4 insects and mite species are the main pests of papaya. This infestation decrease plant vigour and thus affects fruit quality (OECD, 2003).

Fruit flies, the two-spotted spider mite, the papaya white fly and nematodes are the major pests that attack papaya (Morton, 1987).Papaya fruit fly is the major insect pests of papaya throughout tropical and subtropical regions. The insect deposits its eggs in the papaya fruits. The developing seeds and the internal portions of the fruit are fed on by the larvae after 12 days of its emergence. Infested fruits subsequently turn yellow and suddenly drop from the trees prematually. Aphidssuck young leaves of papaya plants which become curled and mottled at the seedling stage. Aphids serve as vectors which transmit viral diseases (Nakasone and Paull, 1998). Thrips, beetles, leafhoppers, moths, mealybugs, whitefly, and sink bug also attack papaya plants (Hunter and Buddenhagen, 1972).

The papaya ringspot is one of the most severe papaya diseases and is often the limiting factor in papaya production throughout the world (Nakasone and Paull, 1998). It causes veins mottling and yellowing spots and water soaking steaks on the petiole. It leads to stunted growth of the plant, fruit size, and sugar content and taste are affected significantly. This disease colonizes very fast and spreads easily and thus become the impeding factor in papaya production throughout the world.

It can be controlled by planting resistant varieties, early planting and also transplanting at a time when there is no or few aphids.Damping-off *(Pythiumultimum)* is caused by fungi. The disease is favoured by high humidity including wet soil, poor drainage, deep sowing, poor soil aeration, high nitrogen in the soil and inadequate sunshine (Hines *et al*., 1965).

Infected seedlings will wilt, fall and then die. The environmental conditions outline above be improved by fumigating the soil with fungicides (Hines *et al*., 1965).

Phytophthora fruit rot (*Phytophthorapalmivaro*) occurs in hot and humid seasons. It causes dieback and root rot on young and adult plant finally dies (Ko, 1982).Also, it causes lesions and mould growth on the fruit which causes the fruit to drop. *Phytophthora* fruit rot can be controlled by crop rotation, selection of well drain soils, avoid harming root or rogue and deeply bury the disease fruits.

Anthracnose (*Glomerellacingulata*) attacks the petioles and the fruit. Symptoms appear on the mature fruit and hence shorten its shelf life. The fungus frequently produces light orange masses of spores (Alvarez and Nishijima, 1987). The disease can be controlled by the treating postharvest fruits with hot water at 490C for 20minutes. It can also be sprayed with 80% Mancozeb (Dithane M- 45) W.P. 1:400 with spreader/ sticker.

Rhizopus Fruit Rot(*Rhizopusstolonifer)* is a fungus that attack mechanically damaged fruits. It produces symptoms of visible black sporangia, and exudation of fluid from the rotting fruit occurs.

## 2.3 POSTHARVEST LOSS

Postharvest losses are classified as those that happen at the farm gate, during storage, in the course of transport, wholesale, retail or at the consumer level. According to (Ceponis and Butterfield 1973), asserted that postharvest losses at the retail level have been measured by storing fruits under conditions that trigger those in the home kitchen by asking housewives to take the weight of all discarded food.

Postharvest losses of papaya along the marketing chain can be attributed to a number of causes. These losses are due to parasitic diseases, physiological disorders, mechanical injuries and fruit overripe. In 1978, the National Academy of Science estimated postharvest losses of papaya to be 40 to 100%. In developing countries like Ghana, large quantity of papaya fruits are wasted before reaching the target markets as a result of limited shelf-life of the fruit and poor postharvest handling (Ignacio *et al.,* 2011). Papaya fruits are cultivated for the local markets and some percentage exported to other importing countries. Postharvest research has been traditionally divided in postharvest physiology and empirical evaluation of handling and storage conditions on quality. Postharvest physiology is concerned with plants or plant parts that are handled and marketed in the living state (Kays 1991). Fruits like papaya are living organs subjected to continuous change after harvesting (Marchal, 1998), hence a considerable amount of the postharvest produce is lost if not properly handled. Quality decline of fruits through high respiration rate, high metabolic activity, moisture loss, softening, yellowing, postharvest decay, and / or loss of flavour and nutritional value leads to significant loss (Wang, 1999). These losses, which, if avoided could positively improve the nutritional status of the poor population dwelling both in cities and rural areas of developing countries (Salunkhe and Desai, 1984). Unfortunately however, a chunk of the harvested plant produce never reaches the consumer or processing centres. With this as the situation, large incomes are lost on one hand and nutritive food to the consumer on the other. Thus, handling, storage and marketing of the crop produce requires serious attention, so as to ensure the produce that needs more input of labour, and capital reaches the consumer with minimal loss (Mattoo and Handa, 2001).

## 2.4 FACTORS AFFECTING POSTHARVEST LOSS

Factors that affect postharvest losses of perishable fruits like papaya vary widely and become more complex as the system of marketing. The ripening of papaya is a complex process, which is strongly affected by pre-harvest and postharvest factors (Lebibet*et al.*, 1995). Like other horticultural crops papaya is high in water content and thus subject to desiccation and mechanical injury, which leads to all stress and attack by bacteria, fungi and other pathological breakdown. The high water content is linked to high perishability and a short shelf-life (Tuker, 1993). It is this perishability and inherent short shelf-life that presents the biggest problem to the successful transport and marketing of this produce. Factors that affect fruit shelf-life and for this reason, cause postharvest loss of fresh papaya can be classified as follows.

## 2.5 PRE-HARVEST FACTORS

In considering quality, it is imperative to begin with pre-harvest, fruit growth and harvest maturity. Unfortunately, in studying the effect of conditions of storage and transportation on the commercial life of fruits, far too little, and often no attention has been given to the pre-harvest factors (Frenkel *et al.,* 1975). Pre-harvest practices set the maximum value for the quality of the fruits. Salunkhe and Desai (1984) have mentioned that although soil type cannot be changed in an established orchard, the contribution the soil makes to the attributes of the developing fruit which affect its postharvest physiology, is greatly influenced by almost every pre-harvest cultural practice. The main pre-harvest factors that influence postharvest performance of the fruits are genetic and environmental (temperature, light, water, nutrient supply, maturity at harvest and application of agricultural chemicals).

## 2.6 CULTIVAR

Although cultural practices and climate are important, pre-harvest factors that affect postharvest performance of the fruits, relatively little attention has been given to cultivar effect on postharvest responses at metabolic level (Watkins and Pritts, 2001). Different cultivars have different degrees of resistance to different stresses and to environmental conditions.Accordingly, the composition of the fruit in relation to flavour, texture, colour, nutritional value, and quality varies considerably, even if the pre-harvest treatment of the plant was the same. A significant effect of cultivar on the shelf-life and quality, weight loss, and ripening of papaya fruit has been reported by (Burden *et al.,* 1993).

The flavour of pear fruit in the ripened condition appears to be largely determined by genetic constitutions and is less influenced by the environment. Similarly, the chilling injury sensitivity, shelf-life, physiological disorder and disease tolerance of citrus fruits after harvest, varies depending upon the cultivar.The following are many varieties or cultivars of papaya available in the market for consumers.

**i. Kapoho solo**: It is pear shape, high sugar papaya with greenish-yellow skin that turns yellow as the fruit ripens. The flesh has peach melon taste.

**ii. Rainbow:** Itis genetically engineered papaya resistant to the ring spot virus diseases. The fruit has greenish-yellow that turns yellow as the fruit ripens with golden-yellow flesh.

**iii. Sunrise:** It is popular by its nickname ‘strawberry’ papaya. Sunrise has greenish-yellow skin that as the fruit ripens.

**iv. Kamlya/ Lala Gold:** It is a rounder, larger fruit than other varieties. It also has a thick arrange flesh.

## 2.7 ENVIRONMENTAL FACTORS

The environmental variables directly influence every aspect of plant growth and development. Climacteric factors including temperature, light, and soil water, have been considered to a lesser extent because they are more difficult to control experimentally (Watkins and Pritts, 2001). Although the climate is difficult to control, knowledge of how it affects postharvest quality is useful in predicting postharvest problems and determining a market policy.

Climatic factors have profound effect on plant phenotype and the extent to which genotypic potential is expressed (Schaffer and Anderson, 1994). Length of storage, respiration, transpiration, chemical composition, external appearance, anatomical structures, decay, taste qualities and other postharvest behaviours and characteristics partly reflect cultural and environmental conditions to which to the produce is exposed. The main climatic factors that affect fruit quality include the following.

**2.8 LIGHT**

As Rom (1996) stated that light has several important functions tree fruit including photosynthesis and photoperiodism, photomorphorgenesis and phototropism. The duration, intensity and quality of light affect fruit colour, sugar accumulation, antioxidant concentrations, and hence, the quality of the fruit at harvest. Moreover, fruits grown under light levels less than 70-80% full sunlight exhibited reduced colour and soluble solids (Rom, 1996).

**2.9 TEMPERATURE**

For most fruits, the higher the temperature during the growth period, the earlier the harvesting time. Temperature effects are related very closely to cell division, probably the most critical time for fruit development (Rom, 1996). High temperature during the vegetative stage hastens growth and reproductive maturity. However, an excessive growth rate can result in misshapen produce and an unpleasant flavour in most fruits (Shewfelt and Prussia, 1993).

According to Rom (1996), the concentration of secondary metabolites in fruits such as colour and flavour can be reduced under higher temperature mainly because of the reduced carbohydrate produced and higher percentage of carbohydrate breakdown to maintain respiration rates at high temperatures. Apart from this, temperature is the driving force for transpiration of plants and hence affects the uptake of nutrients, which later affects the quality of the fruit. On the other hand, Lagerwall (1997) indicated that low temperature, especially during flower initiation inside the pseudo stem of banana plant, cause, 'November dump' (small fruits and malformed fruit). It was also reported by Marler (1994), that papaya fruit flavour tends to insipid if fruit maturation occurs during periods when temperatures above freezing below optimum (21-33$^{0}$C).

## 2.10 WATER SUPPLY

According to Srika and Turner (1995), pre-harvest water deficit reduces green life of the fruit much more than it reduces growth. Insufficient water supply can reduce fruit enlargement and ultimately can lead to wilting, which is serious defect in most fruits (Shewfelt and Prussia, 1993). Fruits of papaya plants which experience high water deficit turn yellowish green colour and die prematurely.

## 2.11 NUTRIENTS

Lack of plant nutrients in the soil can seriously affect the quality and storability of fresh produce at harvest. There are numerous reports of the relationships between mineral composition of the fruit and postharvest disorders involving a number of elements. The nutrient composition of the harvested product is strongly influenced by the nutrition of the parent plant (Kays, 1991). Plant nutrients affect energy flow in the plants since they are essential for photosynthesis and for regulating energy metabolism and carbohydrate transport (Shewfelt and Prussia, (1993). Calcium is one of the essential nutrients that plays an important role in fruit quality and hence postharvest storage life. Many of the physiological disorders occurring in fruit and vegetables are related to calcium content of tissue. Adequate calium in fruits enhances storage life and helps stored fruits to resist a range of breakdown conditions including internal breakdown, low temperature breakdown, water core, lenticel breakdown as well as bitter pit (Weir and Cresswell, 1993). According to Kays (1991) and Salunkhe and Desai (1984), fruits high in calcium have low respiration rate and a longer potential storage life than low calcium fruits. Nitrogen fertilization has been reported to affect quality of various fruits and vegetables. Although nitrogen is essential for plant growth, it delays fruit ripening and leads to soft, poorly coloured fruits with poor storage qualities (Weir and Cresswell, 1993). Lack of potassium brings about poor development, abnormal ripening and respiration rate.

Yield and quality can be affected by potassium deficiency even before leaf symptoms are seen (Weir and Cresswell, 1993). Fruits from potassium deficient plants are often small, poorly coloured and taste insipid. According to (Wojcik*et al.,* 1999), boron is necessary for high yield and quality of apple fruits. It plays a similar role to calcium in plant nutrition, which makes it essential to quality factors such as skin strength, fruit firmness and storage life.

## 2.12 MECHANICAL AND PATHOLOGICAL DAMAGE

Mechanical injuries causing bruising lead to water loss, fungal infection and stimulate respiration ethylene production leading to loss in quality (Phan *et al.,* 1975). Bruise food products like papaya serve as a source secondary entry for decay organisms. Disease attack of fruits after harvest represents one of the sources of postharvest loss (Swinburne, 1983). After harvest, most fruits lose the ability. Fruit characterized by high moisture content and relatively soft peel, are highly susceptible to mechanical damage through their postharvest period. Papaya for example is more susceptible to mechanical damage than other fruits because of their soft texture and moisture content (Salunkhe and Desai, 1984). With this as the situation, decay pathogens can easily enter if poorly handled. Papaya is attacked by a variety of surface and internal postharvest fungi and bacteria (Venter, 1993).

### 2.13 POSTHARVEST FACTORS

Harvested fruits are still living organisms which continue to respire and lose water. They thus, suffer detrimental changes after harvest. Rapid and uncontrolled ripening after harvest is a cause that triggers utilization of energy reserves. Nakasone and paull (1998), further stated that postharvest life terminates because of physiological, mechanical and pathological stress with associated symptoms, such as excessive water loss, bruising, skin scald, failure to ripen and decay.

Biological factors are endogenous factors that affect the postharvest condition of the fruit. They can include the respiration rate, ethylene production, compositional change and /or metabolic activity, transpiration, moisture loss and physiological breakdown. Improper handling and storage of fruits after harvest further enhances biological postharvest loss. These factors include the following.

### 2.14 BIOLOGICAL (INTERNAL) FACTORS

#### 2.14.1 Respiration

Several workers (Wilson *et al.,* 1999), defined respiration as the process by which stored organic material (carbohydrate, protein, and fats) are broken down into simple end products with the release of energy. High respiration rate means loss of stored food reserves which speed up senescence processes, reduced food value for the consumer, loss of flavour especially sweetness and loss of salable dry weight and rapid deterioration and also causes the temperature to rise up and rate of growth of pathogens are accelerated (Kays, 1991). Fruits can be classified into two groups depending on their respiration pattern, as climacteric and non-climacteric. The former can be defined as fruits which can be ripened after harvest in response to ethylene and have a peak in respiration rate during ripening. In the latter case, fruit ripening is protracted and the attainment of the ripened state is not essentially associated with a significant increase in respiration and /or ethylene production (Thompson, 1996). In climacteric fruits however, ripening is associated with increase in the production of ethylene and can accelerate ripening Salunkhe and Desai, (1984). Climacteric fruits including papaya undergo upsurge in respiration and ethylene concomitant with ripening (Frenkel*et al*., 1975).Furthermore, papaya being a climacteric fruit, exhibit a ripening respiration pattern involving the processes of pre-climacteric rise, climacteric peak and post-climacteric periods in the production of carbon dioxide and oxygen. It is important to note that, fruits with the highest respiration rates, such as papaya tend to ripen more rapidly and hence most perishable (Tuker, 1993).

The rate and period of papaya respiration depends on environmental conditions (John and Marchal, 1995). Many researchers reported that decreasing the storage temperature of papaya fruit helps to reduce respiration rate and carbon dioxide production (Lam, 1990) and ripening (Lazan *et al.*, 1993). The rate of respiration ofproduce can be used for adjusting the storage conditions in order to prolong the shelf-life of the commodity. Controlling or modifying these factors to regulate respiration as a possible target is therefore imperative to enhance the quality of the produce.

### 2.14.2 Physiological Disorders

There are myriad of non-pathological disorders found in marketed fruits. The disorders are green, slightly sunken areas on ripe yellow fruit and these are due to abrasion injury that occurs when the fruits are still green (Quintana and Paull, 1993). These disorders are non-pathogenic and hence do not influence ripening.

### 2.14.3 Transpiration

Water loss is one of the main factors that cause fruit deterioration and reduce the market value after harvest. Loss of water from fruits continues after harvest but there are not ways to replace the lost water and thus the fruit continue to deteriorate. Cooling of fruits after harvest is therefore imperative so as to maintain the firmness of fruits. Fruits that have lost 5-8% of their initial weight begin to show signs of mass loss of water and become shriveled (Wilson *et al.,* 1999). Water loss of papaya fruitsis heralded by skin wrinkling although skin discolouration can also be the first symptom (Nakosone and Paull, 1998). The rate of transpiration, which must be minimized to avoid loss in salable weight, wilting and shriveling of produced, can be controlled by good handling at recommended humidity and temperatur. Postharvest water loss is dependent on the commodity, cultivar, pre-harvest conditions, ambient temperature, water- vapour pressure deficit (WVPD), wounds, postharvest heat treatment, and the presence of coating (Nakasone and Paull, 1998), relative humidity and air velocity (Wilson *et al.,* 1999). Ryall and Pentzer (1982) reported that the skin of some fruits develop waxes after harvest. Apart from this, the surface area to volume ratio and stomatal density (Ferris, 1998) of fruits affects the rate of water loss.

### 2.14.4 Firmness

Changes after harvest take place in the cell wall composition and structures resulting in softening of the (Ryall and Pentzer, 1982). The decrease in fruit firmness is a general feature that accompanies ripening of both climacteric and non-climacteric fruits (Biale and Yaung, 1981). The change in firmness can be partly attributed to the starch and sugar changes and the breakdown of pectic substances by pectinase. In papaya fruit, however, softening of fruit mesocarp and endocarp is due to the activity of cell degrading enzymes not due to starch degradation, as the fruit has not accumulated or manufactured starch during ontogeny. It has been reported that the central cavity of papaya fruit can develop a negative pressure which probably associated with changes in flesh gas transfer as it becomes water-soaked due to presumably, loss of cellular compartmentation. It also been demonstrated that there is a close link between firmness of fruit and polygalacturonase activity in the fruit

**2.14.5 Colour**

Theplant world is dominated by the colour green, which is the result of the presence of the chlorophyll pigments (Kays, 1991). For many fruits the first sign of ripening is the disappearance of the green colour with degradation of chlorophyll. It is one of the common symptoms of senescence in harvested produce (Yarmauchi and Watada, 1991). Terblache (1999), reported colour break is a stage of maturity where the green fruit to yellow. In general, colour changes are associated with papaya fruit ripening is an important quality, along with texture, for the determination of eating quality. The change in colour of ripening in papaya fruit is associated with the breakdown of chlorophyll with already presented carotenoids level remaining relatively constant John and Marchal, (1995). An increased in carotenoid level was during ripening in papaya fruit and pepper.The principal agents responsible for chlorophyll degradation are $P^H$ change mainly due to leakage of organic acids from the vacuoles, chlorophyll oxidative system, chlorophyllase (Wills *et al*., 1998), light, temperature (Kays, 1991) and cultivar (Robbins and Moore, 1990). Within the natural environment, both high and low temperatures have been implicated in the destruction of chlorophyll (Hendry *et al.*, 1987). Similarly, several plant growth regulators have been shown to have a significant effect on the pigmentation of some harvested produce. Cytokinins and gibberellins ($GA_3$) were reported to retain chlorophyll (Kays, 1991) and retard fruit ripening and senescence process in fruits, and thus maintain green colour for a longer period (Barkai-Golan, 2001). The colour of any that is edible enhances the determination of quality by consumers. Also, the colour of papaya fruit is often the major postharvest criterion by researches, growers, and other stakeholders to determine whether the fruit has reached its physiological maturity stage (Medlicott*et al.*, 1992).Colour charts or colour measuring instruments are used for this purpose.

### 2.14.6 Change in pH

In most fruits, pulp pH is an important postharvest attribute in the assessment of fruit ripening quality. Pulp pH rapidly declines in response to increasing ripeness. Generally when fruits are harvested at mature green stage, the pulp pH is high but as ripening advances, pH declines.

### 2.14.7 Total Titratable Acidity

The pattern of organic acids changes in fruits is concomitant with ripening. The major chemical compounds found are ester of aliphatic alcohols and short chain fatty acids. In most fruits an increase in sugar content and decrease in acidity is evident during ripening Illeperuma and Jayasuriya, (2002). Acid can be considered as a reserve source of energy to the fruit, and would therefore be expected to dip during ripening (Wills *et al.*, 1998).The sugar and acid have influenced on the sensory attributes of the fruit (Ackermann *et al.*, 1992). In papaya the predominant acids are malic and citric acids, the presence of tartaric, malonic, fumaric and succinic was also detected.Usually, organic acids reduce during ripening (Wills *et al*., 1989). Acidity in the pulp tissues of papaya increases during ripening. Titratable acidity was reported to increase during ripening and declined afterward in papaya (Selvaraj *et al*,. 1982).

### 2.14.8 Sugar /Acid Ratio

Papaya can be categorized into two types including cell wall polysaccharides and soluble sugars. Quality fruit is determined by the sugar content. Sucrose content increases during ripening (Hulme, A.C, 1971). The postharvest chemical change that happens in the course of ripening of fruits is the hydrolysis of starch and the accumulation of sugar, which are responsible for sweetening of the fruit as it ripens. In papaya, the breakdown of starch and the synthesis of sugar are usually completed at full ripeness and continue in over-ripe and senescence of the fruit (Marriott, 1981).

### 2.14.9 Total Soluble Solids

During ripening in papaya, the total soluble solids increase. In ripe papaya, sugar forms the main component of the total soluble solids (Gomez *et al.*, 2002) since the amount sugar in fruits usually surges as the fruit ripens. The soluble solids content of the fruit can be useful index of quality for ripeness. To attain maximum total soluble solids in solo papaya, the yellow colour must cover 6% of the fruit surface.

## 2.15 SHELF-LIFE

It is simply the time that the fruit can be expected to maintain alevel of quality under a particular storage conditions. Shelf-life begins immediately the green life of the fruit ends (Aked, J. 2000). Shelf-life is pivoted on texture firmness due to cell wall degradationresulting in changes in starch (Yashoda *et al.*, 2006). Fruit softening rate is a feature that determines fruit shelf-life (Brummell and Harpster, 2001).

### 2.15.1 Weight Loss

Papaya fruits loss weight as water is lost from the fruits. The fruits mayreduce in weight during the warm dry part of the day as temperatures advances (Ryall and Pentzer, 1982). This owes to the fact that after harvest the process of moisture loss persists and at this point there is no way to replace the loss moisture. Moisture content of most fruits is high and thus, weight lost during transport and storage is a serious concern (Ryall and Pentzer, 1982). Weight loss of 5% will cause fruits to be shriveled and misshapen in high temperature levels. Excessive water loss can lead to loss of crispness and unwanted colour and palatability (Wills *et al.,* 1998). The level of weight loss of fruits will depend on the type of fruit, size, shape, composition and structure, relative humidity during storage (Ryall and Pentzer, 1982).

### 2.15.2 Atmospheric Composition

Naturally the atmospheric composition around the fruit is composed of 78% of nitrogen, 21% oxygen and 0.03% carbon dioxide. Shelf-life extension is assured if the above mentioned factors are modified.The composition of the gaseous atmosphere to which postharvest fruits are exposed can affect both respiratory and the metabolic rate of the produce (Kays, 1991). When carbon dioxide levels within the storage environment is increased and oxygen levels decreased help to inhibit respiration rate (Phan *et al.,* 1975) and hence reduce fruit ripening. Salunkheand Desai (1984) reported that high carbon dioxide prevents the disolution of peptic substances and retains fruit texture and firmness for longer periods. Hence, carbon dioxide and oxygen is essential for each fruit.

The ideal control atmosphere storage of papaya is 3-5% oxygen and 5-8% carbon dioxide (Kader, 2000).

### 2.15.3 Reduction Techniques

A better understanding of the control of ripening is very imperative because it has implications for fruit shelf-life and storage quality. Several attempts have been made in order to control ripening. Thus, different methods and chemicals have been employed and apply for the control and reduction of postharvest losses. These chemicals are applied to crops to control microorganisms and pests invading which hitherto shorten the storage life of fruits. Aside this supplemental treatment like control atmosphere, modified atmosphere, irradiation, film packaging, waxing; chemicals are also used (Wang, 1999). Also, papaya being a climacteric fruit is characterized by high respiration rate and ethylene production during ripening. According to (Ali *et al.,* 1994), the shelf-life of papaya is between 7-9 days after harvest. Thus, good storage practices are needed so as to prevent postharvest quality deterioration.An added important point is that, fungicides are used to control postharvest diseases of fruits, environmental and health risks are high (Janisiewicz and Korten, 2002).

## 2.16 PLANT GROWTH REGULATORS (PGRS)

Understanding the role of these PGRs in the regulation of fruit ripening still represents a major challenge the postharvest technologist. Information on the effect of these compounds applied in postharvest is extensively only for ethylene (Wills *et al.,* 1998). PGRs have been used to control fruit decay after harvest.

According to Barkai-Golan (2001), PGRs may be similar to low temperature, suppress decay development indirectly, by slowing ripening process in the fruits.However, recent advances in the knowledge of the biosynthesis now provide more rational basis on which to interpret the effect of certain types of exogenously applied PGRs (Sharpless and Johnson, 1986). Naturally occurring plant growth substances, their chemical analogs and antagonists, most certainly play a role in growth and development, and therefore must in some way influence the development of ripening capacity.

### 2.16.1 Characteristics of Plant Hormones

Theword hormone is derived from Greek and means 'set in motion.' According to Strivastava (2002) that a large number of related chemical compounds are synthesized by humans, and are used to regulate the growth of cultivated plants, weeds and in vitro grown plant cells. These artificial substances are called plant growth regulators (PGRs). Plant hormones are not nutrients but chemicals that in small quantities promote the growth, development and differentiation of cells and tissues (HelgiOpik, 2005).

### 2.16.2 Classes of Plant Hormones

#### 2.16.2.1 Auxin

They are growth substances that are produced in significant quantities in the upper growth region of plants. Theendogenous auxin in ethylene biosynthesis is not properly understood, but evident indicates that IAA may be the ripening inhibitor in apple and pears, which some researchers claim to be present in the tree. It was also found that vacum-infiltration of banana fruits slices with 2, 4-D or IAA delay the onset of ripening, although ethylene production was stimulated.  Softening and degreening were inhibited increasingly in response to increasing concentration of IAA in tomato.

#### 2.16.2.2 Gibberellic acid

They include a large range of chemicals that are produced within plants naturally by fungi. They were first discovered when a Japanese researcher; Eiichi Kurosawa found a chemical manufactured by a fungus called, *Gibberella fujikuroi* which grew abnormally in rice (Grennan, 2006). Gibberellins are important in seed germination affecting enzyme production, mobilizes food production used for growth of new cells (Tsai *et al*., 1997). Gibberellins (GA3) possess the capacity to trigger growth plant species. More than 130 GA3 are known, although only a few are active biologically (GA1, GA3, GA4 and GA7) of which only GA3 and a mixture of GA4+GA7 are available as a commercial marketed products. They are also commercially available (Diaz, 2002), and GA3 is the most extensively applied in agriculture. Gibberellic acid (GA3) is prepared into a liquid solution (2 to 5% of GA3 in isopropyl alcohol or 10% of GA3 in methyl alcohol), as a soluble powder (5 to 20% of GA3), in effervescent tablets of 1 to 10g of GA3 and in soluble granules (40% of GA3).

Postharvest dipping of papaya in aqueous solutions, of GA3 delays colour and aroma development, retard chlorophyll degradation, ascorbic acid decreases and there is the decline in activity of amylase and peroxidase Similarly, Kotecha and Desai (1995) reported that an increase in firmness, starch, cellulose, and hemicellulose content was observed when papaya was treated with GA3. Also, postharvest treatment of papaya fruit with GA3, vitamin K, silver nitrate and cobalt chloride were found to extend shelf-life without any adverse effect on palatability (Metha *et al.,* 1986).

#### 2.16.2.3 Cytokines

Another plant hormone believed to retard fruit ripening is cytokines. Senescence in leaves can generally be delayed by cytokines treatment of fruit can retard senescence phenomenon. It was observed that high level of accumulated endogenous cytokines delay fruit ripening and the level of this compound declines as ripening proceeds.

#### 2.16.2.4 Abscisic acid ethylene

In general, it acts as an inhibiting chemical compound that affects bud growth, seed and bud dormancy.

Ethylene is a gas that forms through the Yang cycle from the breakdown of methionine which is found in cells (Wang *et al.*, 2007). Fruit ripening is a coordinated series of biochemical changes that renders the fruit attractive to eat. This process is under genetic regulation, but plat hormones play an essential role. Ripening in climacteric fruits is accompanied by evolution of ethylene. Ethylene is a colourless gas with sweetish scent that is naturally produced ripening hormone of most fruits, and also involves in the regulation of many aspects of growth, development and senescence (Yang *et al.*, 1986).

Ethylene is essential for the initiation of fruit ripening, although other factors are believed to be involved (Salunkhe and Desai, 1984). All fruits produce ethylene, but climacteric fruits are characterized by an enormous increase in ethylene production (John and Marchal, 1995; Kays, 1991) as well as increase in respiration rate. Ethylene is synthesized from sulfur containing amino acid and methionine**.** Methionine is first converted to S-adenosyl methionine (SAM) and then to the 4-carbon compounds, 1-amino-cyclopropane-1-carboxylic acid (ACC) via the enzyme ACC synthase.

The excess production of ethylene beyond the optimum level warrants changes in fruit physiology from maturation to ripening. Lau *et al.*, (1985) have examined the change in ACC content during the ripening of apple. Regulation of ethylene biosynthesis and actions is very important. It has been shown that the production of ethylene can be reduced by decreasing temperature, reducing oxygen, increasing carbon dioxide, treating with inhibitors (aminoethoxy-tras-3butenoicacid, aminovinyl glycine, cobalt chloride, and plant growth regulators (GA3, Cytokinins and auxin) help to extend the shelf life of fruits (wills *et al.*, 1998).

## 2.17 RIPENING

During growth, papaya steadily accumulates starch. They first elongate their increase in width. The increase in width continues as long as the fruits are not harvested and thus, they become rounded or oval (Grierson *et al.,* 1981). Papaya is picked green and ripens under controlled, temperature, relative humidity and ventilation to prevent the accumulation of carbo dioxide. Normal ripening will occur at $5^{O}C$ or higher concentration of oxygen. Ripening of papaya is represented by a sequence of changes in the colour of the peels from green to yellow, as defined by a colorimetric scale from 1 to 7 (Anon, 1990) and the texture and flavour of the pulps. Papaya fruit ripening is a process that culminate in changes in colour, texture, flavor of the fruit flesh (Grierson and Alexander, 2002). The difference between fruit ripening and senescence has not been clearly defined. Some school of thought have pointed out that ripening is ‘the sum total of changes that occur from the latter stages of growth and development through the early stages of senescence and thus leads to aesthetic or food quality. Fruit can be divided into two: climacteric and non-climacteric. Climacteric fruit promotes normal ripening after the fruit is harvested from the parent plant (Grierson and Alexander, 2002). The non-climacteric however ripens on the mother plant before harvest. As ripening progresses, flavor develops as the sugar-acid is changed by starch hydrolysis and soluble sugar accumulation, phenolic levels change and volatile production increases (Giovannoni, 2001).

## 2.18 MATURITY INDICES

Maturity indices are necessary for determining fruit should be harvested so as to enhance product acceptability in the market (Eskin, 1991). Fruits that are to be shipped overseas have to be harvested at mature green stage. Most maturity indices are also factors of quality. However, there are many important quality indices that are not applied in determining harvesting stage. Maturity at harvest is very necessary in depicting storage life of the fruits and quality. Fruits that are not matured are highly susceptible to shriveling, mechanical damage and are of poor quality when ripe (Nagy, 1980). Also, fruits that are harvested too late or over ripe have shorter storage life owing to susceptibility to physiological disorders.Maturity indices used presently are depended on indices that will enhance the best eating quality to the consumer (Pattee, 1985).

## 2.19 OPTIMUM STORAGE CONDITIONS

Harvested papaya fruits are still alive after they have been harvested from the mother plant. Thus they continue to lose water that cannot be replaced by the parent plant. With this as the situation, the respiratory substrate and water loses that occur triggers undesirable changes in the fruits. Many pre-harvest and postharvest factors such as cultural practices, genetics, maturity at harvest and postharvest techniques influences the composition and quality of fruits by the time it reaches the final consumer. However, postharvest treatments cannot improve fruit quality beyond the fruits harvested or ripened on the parent plant can only slow down the rate of deterioration. Once harvested, storing fruits within their optimum temperature and relative humidity are the most important factors for fruit quality maintenance.Fruits should also be stored from 7 to 13$^{O}$C with 90 to 95 % relative humidity. At 7 to 10$^{O}$C ripening occurs slowly. Papaya fruits at colour breaking stage can be stored at 7°C for 14 days and will ripen normally when transferred to room temperature (Thompson and Lee, 1971).

## CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 INTRODUCTION

The study was in two phases. The first phase was a survey which comprised field observation and questionnaire administration. The second phase was conducted at the laboratory of the Department of Horticulture at the Kwame Nkrumah University of Science and Technology (KNUST).

### 3.2 SURVEY

A preliminary field survey was conducted to sample views from papaya producers on shelf-life and quality of papaya fruits after harvest. The survey targeted papaya farmers in the Akwapim South Municipality who produce papaya fruits.

### 3.3 FIELD WORK AND DATA COLLECTION

A field survey was conducted in farming communities in Akwapim South municipality in order to obtain first-hand infor.mation in areas where farmers cultivate papaya intensively. The field survey was then followed by identification and selection of communities for the study.

### 3.4 COMMUNITY SELECTED FOR THE STUDY

Stratified sampling technique was employed to group the communities in the municipality into papaya producing and non-papaya producing areas. Purposive sampling method was then used to select fifteen (15) communities in the municipality where papaya is grown commercially. The communities included, Ahwerease Daman, Noka, KwasiTenten, Yaw Krow, NsawamAdoagyire, Akwamu, Gyatwie, Kofi Nsa, Ayigbentey,Otoase, Amfaso, Teacher Mantey, Krabo, Marfo Krom and Asuboi. These communities were selected for the study owing to the fact that they are the major producing areas in the municipality.

## 3.5 TARGET GROUP AND SAMPLE SIZE

The study targeted papaya producers in the municipality. One hundred and fifty papaya farmers were selected from the fifteen (15) communities chosen and used as the sample size for the study. Ten (10) papaya farmers were randomly selected from each of the fifteen (15) communities in order to avoid bias.

## 3.6 METHODS

### 3.6.1 Questionnaire Design and Administration

Having conducted the preliminary survey in the Akwapim South Municipality between the months of April and May, 2016, questionnaires were designed for administration. Both closed and open ended questions were structured and administered to one hundred and fifty (150) papaya farmers. The questionnaires were administered by interviewing the respondents. Data was collected on the background of respondents, sex, age, years in papaya production, shelf-life of papaya after harvest, varieties used in production, major postharvest problems among others.

## 3.7 EXPERIMENTAL LOCATION

The laboratory experiment or work was carried out at the Department of Horticulture Laboratory at the Kwame Nkrumah University of Science and Technology Kumasi, where total titratable acidity (TTA), Firmness, colour, weight loss, Total soluble solids (TSS), pH, moisture content, sugar/acid ratio, and shelf-life were determined.

## 3.8 LABORATORY EXPERIMENT

The laboratory work was the application of gibberellins ($GA_3$) at the concentrations of 100mg/litre, 200mg/litre, and 300mg/litre and a control for the duration of two (2) weeks and two (2) days. The work started from April to May, 2016.

## 3.9 SOURCE OF PAPAYA FRUITS

Papaya varieties used for the Laboratory work for the study were Kapoho and Sunrise. Fruits were obtained from a single farmer in one of the fifteen (15) papaya fruit growing communities, for the study during the field survey.

## 3.10 EXPERIMENTAL DESIGN AND TREATMENT

The experiment was a 2×4 factorial laid in Completely Randomized Design (CRD) with 3 replications. The experimental factors were papaya varieties at 2 levels (Kapoho and Sunrise) and plant growth regulator (Gibberellins) at 4 levels (0mg/litre, 100mg/litre, 200mg/litre and 300mg/litre).

There were eight treatment combinations as follows:

1. Sunrise + 0mg/litre
2. Sunrise + 100mg/litre
3. Sunrise + 200mg/litre
4. Sunrise + 300mg/litre
5. Kapoho + 0mg/litre
6. Kapoho+ 100mg/litre
7. Kapoho + 200mg/litre
8. Kapoho+ 300mg/litre

## 3.11 EXPERIMENTAL MATERIAL

Thirty-six (36) papaya fruits each from the two varieties at colour- break stage were selected. These fruits were carefully selected or harvested according to export standard. The harvesting was done in the morning when the temperature was low. This was done or carried out carefully in order to prevent any mechanical injuries or damages on the fruits. A standard colour chart for harvesting papaya fruits for export was used as a guide.

The fruits were then packed or packaged separately according to the two varieties in different paper boxes and taken to the Laboratory of the Department of Horticulture at the Kwame Nkrumah University of Science and Technology (KNUST).

## 3.12 SAMPLE PREPARATION

On arrival at the premises of the Laboratory, the papaya fruits were sorted for uniform size, shape and free from mechanical damage or injuries. The papaya fruits were then washed thoroughly and carefully under running tap water to get rid of any dirt and latex.

## 3.13 GIBBERELLINS (GA3) PREPARATION

The $GA_3$ powder was weighed into100mg, 200mg and 300mg respectively. The above concentrations were dissolved in water for thirty (30) minutes at 100mg/litre, 200mg/litre and 300mg/litre respectively.

The three (3) papaya fruit varieties were then dipped into the various concentrations for five (5) minutes. This was to allow the papaya fruits to imbibe the solution of the $GA_3$ concentrations. After the five (5) minutes, the papaya fruits were air-dried and then placed in their respective replications with the control. Fruits treated with $GA_3$ were then monitored for physiological changes such as weight loss, firmness, shelf-life among others.

## 3.14 LABORATORY STUDIES ON THE PHYSIOLOGICAL CHANGES OF PAPAYA FRUITS

### 3.14.1 Total Titratable Acidity

Fifty (50) grams of papaya fresh pulp was weighed and put into a kitchen blender and fifty (50) ml of distilled water was added to the contents in the blender. The contents were then blended 6 minutes and filtered with a sieve. Fifty (50) ml of the filtrate was transferred into a conical flask and 3-5 drops of phenolphthalein indicator were added. A fifty (50) ml burette was filled with 0.1 M of sodium hydroxide (NOAH). The sodium hydroxide (NAOH) solution was added drop by drop to the contents in the flask until the colour changed to pink for at least 30 seconds. The titre volume of the NAOH added was then recorded.

### 3.14.2 Total Soluble Solids

Fifty (50) grams of papaya fresh pulp was placed in a kitchen blender with the addition of 50 ml of distilled water and blended for 6 minutes, and thus filtered with a filter paper. A few drops of the juice were added onto the stage of the refractometer and thus the brix reading was recorded.

### 3.14.3 Measurement of Firmness

The measurement of the papaya fruit firmness was done according to the recommended method by AOAC, 1990. Papaya fruits were cut at the middle portion longitudinally with a sharp knife. The fruits cut with both peel and pulps were faced up in a plat form. The force needed to penetrate the pulp tissue with the 6mm diameter cylindrical probe penetrometer or tester (hustron 444 penetrometer) was recorded in kilograms.

### 3.14.4 PH Determination

Fifty (50) grams of papaya fruit pulp was weighed into a kitchen blender. Fifty (50) ml of distilled water was added. This was followed by blending for 6 minutes and the contents filtered. The electrode was first washed in distilled water and subsequently placed in the filtrate for six (6) minutes for the pH values of the filtrate to be recorded.

### 3.14.5 Sugar: Acid Ratio

Fifty (50) grams of fresh of papaya fruits were weighed in a kitchen blender, blended for six (6) minutes and filtered. Ten (10) ml of the filtrate was pipetted into 250 ml beaker. Fifty (50) ml of distilled water was added to the 10 ml juice in the 250 ml beaker and 3-5drops of phenolphthalein were added. Twenty (25) ml burette was filled with 0.1 M of sodium hydroxide (NAOH). The 0.1 M of NAOH was then titrated with the filtered juice and phenolphthalein until the colour changes to pink. The volume of the NAOH was thus recorded.

### 3.14.6 Weight Loss

The measuring balance was put on a flat surface ensuring that it was well balanced. It was then switched on and tared to zero. The fruit to be weighed was put on the measuring balance, making sure it was placed on at the center of the measuring balance. The readings were taking and recorded.

Weight losses of fruits were determined by weighing fruits every day with the aid of the measuring balance.

Weight losses were calculated as percentage of the initial weight.

Weight loss (%) = W1 - W2 x 100 /W1

Where W1 = initial weight, and W2 = final weight.

### 3.14.7 Moisture Determination

The papaya fruit sample was dried in an oven at a temperature of $95^0$C– $110^0$C for 24 hours. The procedure is as follows:

Moisture can or crucible was weighed followed by 1 to 2g of granular sample of papaya fruit pulp and put into the moisture can. These were allowed to dry overnight in an oven at $110^0$C for 24hours. After the 24 hours the crucibles and samples in the desiccator were cooled and re-weighed

Calculations:

$(A+B) – A = B$

$(A +B) – (A +C) = B – C =D$

% moisture = $D / B \times 100$

Where A = crucible, B = sample weight (wt), C = dry sample wt, D = moisture wt

### 3.14.8 Measurement of Colour

Fruits colour was classified according to fruit peel colourand visually corresponding the colour of the peel to a standard colour chart for papaya fruits for export (AOAC, 1990).

The chart used as a guide for the colour (1-8) determination is shown below.

1: Green skin without yellow stripe

2: Green skin with light yellow stripe

3: Green with well-defined yellow stripe

4: One or more yellow stripe

5: Fairly orange – coloured skin

6: Clearly orange – coloured skin with light green areas.

7: Characteristic orange – coloured skin

8: Fruit colour similar to 7 but more intense.

### 3.15 MEASUREMENT OF SHELF -LIFE

Shelf-life starts right after the green life of the fruit ends. Shelf-life was determined by regular visual inspections of the fruit. Shelf-life was determined as the period in days between the commencement of the ripening and the end of saleable life or edible life.

### 3.16 SENSORY ANALYSIS

Sensory evaluation of the papaya fruits for pulp colour, aroma, taste, mouth feel and general acceptability for all the samples were performed at the end of the storage period using 5- point Hedonic scale as described by Larmond, (1997).

Twenty (20) papaya fruits were served to the panelist including fresh papaya fruit as the control for their evaluation. The panelists were asked to score the sensory attributes according to the 5- point Hedonic scale (5 = like very much, 4 =like moderately, 3 = neither like nor dislike, 2 = dislike moderately and 1 = dislike very much).

### 3.17 DATA ANALYSIS

The primary data collected from the field survey was analysed with Statistical Package for the Social Sciences (SPSS) Version 16.0 and the results presented in Tables, Pie charts and graphs.

Laboratory data was statistically analyzed using statistix (Version 9) statistical software for Analysis of variance (ANOVA). Means separation of the treatments were performed by the Least Significant Difference (LSD) test at 1% ($p$ = 0.01) levels for the physical and chemical analyses.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 SEX OF PAPAYA FRUIT PRODUCERS

Figure 4.1 shows that 75% of the farmers were males whilst the females' population constituted only 25%.

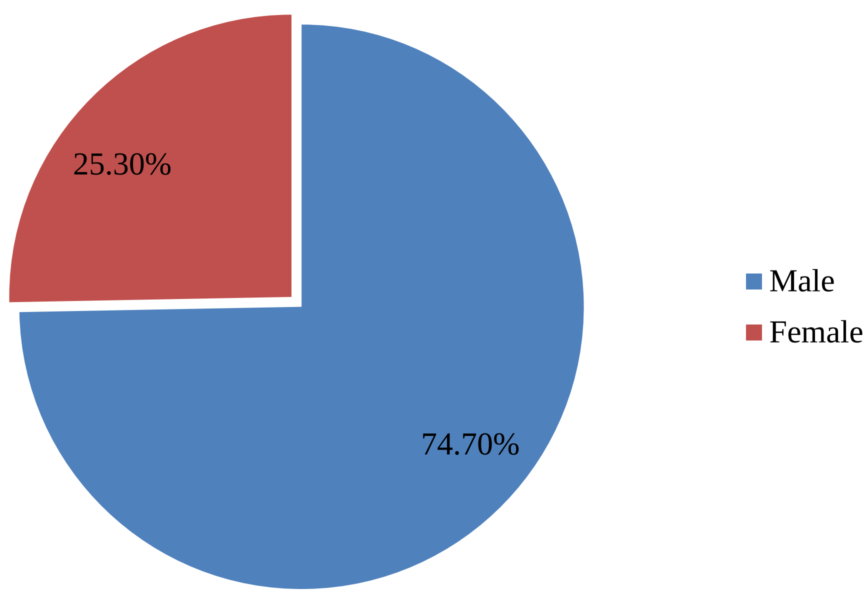


Figure 4.1: Sex of respondents

### 4.2 AGE DISTRIBUTION OF FARMERS

Table 4.1 showed that 62% of the respondents were within the ages of 18 to 50 whilst 38% were above 51 years.

Table 4.1: Age distribution of papaya farmers

| Age | Frequency | Percentage (%) |
|---|---|---|
| 18 – 30 | 33 | 22 |
| 31 – 40 | 31 | 20.6 |
| 41 – 50 | 29 | 19.3 |
| 51 – 60 | 26 | 17.3 |
| > 60 | 31 | 20.6 |
| Total | 150 | 100 |

Source: Field survey, 2016

**4.3 LEVEL OF EDUCATION OF RESPONDENTS**

The educational level of farmers is presented in Table 4.2. The study revealed that 57% of the respondents have at least some basic education. However, 43% of the respondents did not have formal education.

Table 4.2. Educational level of respondents

| Education | Frequency | Percentage (%) |
|---|---|---|
| Primary | 42 | 28 |
| JSS/Middle School | 6 | 4 |
| SHS | 35 | 23 |
| Tertiary | 2 | 1.3 |
| No formal education | 65 | 43.3 |
| Total | 150 | 100 |

Source: Field survey, 2016

## 4.4 PAPAYA VARIETIES GROWN BY FARMERS

From Figure 4.2, 60% of the respondents cultivated Kapoho whilst only 40% of the farmers' populations cultivated Sunrise variety.

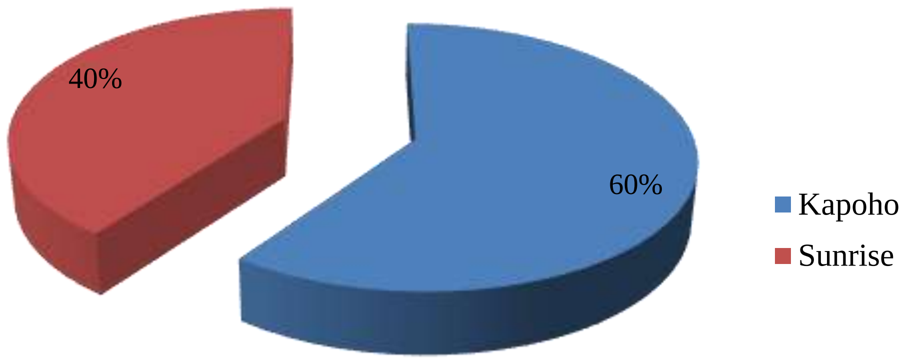


Figure 4.2: Papaya varieties grown by farmers

## 4.5 SHELF-LIFE OF PAPAYA FRUITS AFTER HARVEST

Table 4.3 shows the maximum number of days papaya took to ripen under ambient storage conditions. Most (36.6 %) of the farmers responded that the fruit took 7 days to ripen. However, one farmer (0.7%) each responded that papaya took 1 and 2 days to ripen.

Table 4.3: Shelf life of papaya fruits after harvest

| Days | Frequency | Percentage (%) |
|---|---|---|
| 1 | 1 | 0.7 |
| 2 | 1 | 0.7 |
| 3 | 8 | 5.3 |
| 4 | 18 | 12 |
| 5 | 14 | 9.3 |
| 6 | 53 | 35.3 |
| 7 | 55 | 36.6 |
| Total | 150 | 100 |

Source: Field survey, 2016

### 4.6 MAJOR PROBLEMS ENCOUNTERED DURING PAPAYA PRODUCTION

Table 4.4 presents major problems farmers face during papaya production. The results revealed that majority (76 %) of the farmers had short shelf life for the produce after harvest. Twenty-five respondents (16.7 %) faced transportation problems after harvesting of the fruits. Two farmers (1.3 %) each responded that they had problems with high cost of weedicides and lack of ready market. The least (0.6 %) problem farmers faced in the study area was pest infestation.

Table 4.4: Problems during papaya production

| Major problems | Frequency | Percentage (%) |
|---|---|---|
| High cost of weedicides | 2 | 1.3 |
| Lack of ready market | 2 | 1.3 |
| Pest infestation | 1 | 0.6 |
| Shelf life of papaya | 114 | 76 |
| Storage problem | 6 | 4 |
| Transportation | 25 | 16.7 |
| Total | 150 | 100 |

Source: Field survey, 2016

**4.6. LABORATORY ANALYSIS**

**4.6.1 Percentage Moisture Content of Papaya Fruits Varieties**

Table 4.5 shows that the moisture content was significantly ($p$ = 0.01; $p$ = 0.01) affected by both gibberellins application and varieties of papaya. Sunrise variety of papaya recorded a mean lower moisture content of 86.1% whilst Kapoho recorded a mean higher value of 87.3%. However, significant differences were observed between the two varieties of papaya. The mean moisture content of papaya from concentration of gibberellins application ranged from 85.0% to 88.1%. Papaya fruits applied with 300mg/litre had the highest mean moisture content of 88.1% which was significantly different from the rest of the concentrations.

The interaction effect was statistically significant ($p$ = 0.01). Kapoho variety applied with 300mg/litre of gibberellins recorded the highest moisture content of 88.7% which was significantly higher than sunrise variety applied with the same concentration with moisture content value of 87.5%.

Table 4.5: Effect of papaya varieties and growth regulator (Gibberellins) on percentage moisture content

| **Papaya variety** | **Concentration of Gibberellins (mg/litre)** | | | | **Mean** |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | |
| **Sunrise** | $83.5^{d*}$ | $86.5^{c}$ | $87.0^{bc}$ | $87.5^{b}$ | **86.1**$^{b}$ |
| **Kapoho** | $86.5^{c}$ | $87.0^{bc}$ | $87.2^{bc}$ | $88.7^{a}$ | **87.3**$^{a}$ |
| **Mean** | **85.0**$^{c}$ | **86.8**$^{b}$ | **87.1**$^{b}$ | **88.1**$^{a}$ | |
| **CV (%) 0.33** | | | | | |

*****Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

### 4.6.2 Effect of Papaya Varieties on Firmness

The effect of varieties of papaya fruit on firmness was not statistically significant ($p$ = 0.29).

### 4.6.3 Effect of Concentrations of Gibberellins on Firmness of Papaya Fruits

The 4.6 showed the various concentrations of gibberellins on firmness showed statistical significance ($p$ = 0.01). Concentration of 300mg/litre recorded the most firmness (4.65N), but was statistically similar to 200mg/litre concentration which recorded a value of 3.02N. The control fruits had the least firmness (0.60N). Significant difference was not observed between concentration with 100mg/litre and the control (0mg/litre).

Table 4.6: Effect of Gibberellins concentrations on firmness of papaya fruits

| Concentrations (mg/litre) | Firmness (N) |
|---|---|
| 0 | 0.60$^{c}$ |
| 100 | 1.26$^{bc}$ |
| 200 | 3.02$^{ab}$ |
| 300 | 4.65$^{a}$ |
| **Means 2.38** | |
| **C. V. (%) 48.68** | |

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

### 4.6.4 Effect of Papaya Varieties and Gibberellins Concentrations on Firmness

There were no significant ($p = 0.02$) interaction between papaya varieties and gibberellins concentrations.

### 4.6.5 Effect of Papaya Varieties on Shelf- Life

The effect of papaya varieties on shelf- life is presented in Table 4.7. Significant differences ($p = 0.01$) were observed between the two varieties. Fruits of Kapoho variety had significantly longer shelf-life (11) than sunrise (10).

Table 4.7: Effect of papaya fruit on shelf-life

| Papaya Variety | Shelf-life (Days) |
|---|---|
| Sunrise | 10.1$^{b}$ |
| Kapoho | 11$^{a}$ |
| **Mean** | **10.5** |
| **CV 6.7** | |

***Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

#### 4.6.6 Effect of Gibberellins Concentration on Shelf- Life of Papaya Fruits

The effect of gibberellins concentration is presented in Table 4.8. Significant differences ($p$ = 0.01) were observed among the concentrations that were applied. Papaya fruits applied with 300mg/litre took significantly more days (15) to end their saleable life, whilst the fruits without the concentrations (control) to significantly the shortest days (6) to end their shelf life.

Table 4.8: Effect of gibberellins concentration on shelf-life of papaya fruits

| Concentration (mg/litre) | Shelf life (Days) |
|---|---|
| 0 (control) | $5.7^{d}$ |
| 100 | $9.7^{c}$ |
| 200 | $11.5^{b}$ |
| 300 | $15.3^{a}$ |
| **Mean** | **10.5** |
| **CV 6.7** | |

*Means in columns carrying the same superscript letter are not significantly different at $p$ = 0.01

#### 4.6.7 Effect of Papaya Varieties and Gibberellins Concentrations of Shelf Life.

There were no significant ($p$ = 0.22) interaction between papaya varieties and gibberellins concentrations on shelf life.

#### 4.6.8 Weight (G) of Papaya Fruits

The weight of papaya fruits is presented in Table 4.9. From the Table significant differences ($p$ = 0.01) were observed for the concentrations of gibberellins applied. Fruits dipped in Gibberellins concentration of 300mg/litre recorded the largest mean weight of 35.8g which is significantly different from the control which recorded a mean value of

9.4g. However, fruits dipped in $GA_3$ concentrations of 100mg/litre and 200mg/litre recorded mean values of 29.4g and 33.6g respectively which were statistically similar to concentration of 300mg/litre. Significant differences ($p$ = 0.75) were not observed between the papaya varieties. The interaction effect was also not significantly different ($p$ = 0.92).

Table 4.9: Effect of papaya varieties and growth regulator (Gibberellins) on weight (g)

| **Papaya variety** | **Concentration of Gibberellins (mg/litre)** | | | | **Mean** |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | |
| **Sunrise** | $8.3^{b*}$ | $28.0^{a}$ | $34.6^{a}$ | $35.6^{a}$ | **26.6**$^{a}$ |
| **Kapoho** | $10.5^{b}$ | $30.8^{a}$ | $32.6^{a}$ | $36.0^{a}$ | **27.5**$^{a}$ |
| **Mean** | **9.4**$^{b}$ | **29.4**$^{a}$ | **33.6**$^{a}$ | **35.8**$^{a}$ | |
| **CV (%) 23.7** | | | | | |

***Means in columns carrying the same superscript letter are not significantly different at $p$ = 0.01

### 4.6.9 Effect of Papaya Varieties on pH

There was no significant difference ($p$ = 0.54) between the papaya varieties.

### 4.6.10 Effect of Gibberellins Concentration on pH

The effect of gibberellins concentration on pH is presented in Table 4.10. Significant differences ($p$ = 0.01) were observed among the various concentrations. The control treatment (0mg/litre) recorded significantly the highest pH of 6.68. No significant difference was observed between 100mg/litre and 200mg/litre. Concentration of 300mg/litre recorded significantly the least pH of 4.47.

Table 4. 10: Effect of concentrations on pH

| Concentrations (mg/litre) | pH |
|---|---|
| 0 | 6.68[a] |
| 100 | 5.75[b] |
| 200 | 5.36[b] |
| 300 | 4.47[c] |
| **Mean** | **5.57** |
| **C. V. (%)** 13.86 | |

***Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

### 4.6.11 Effect of Papaya Varieties and Gibberellins Concentrations on pH

There were no significant ($p = 0.99$) interaction between papaya varieties and gibberellins concentrations.

### 4.6.12 Effect of Interaction on Total Soluble Solids

The effect of papaya varieties and gibberellins on TSS is presented in Table 4.11. The mean value of TSS between the varieties ranged from 11.83 to 12.92 $^{o}$brix whilst the mean value among the concentrations ranged between 10.33 and 14.75 $^{o}$brix. Kapoho variety recorded a significantly higher TSS than sunrise variety. For the gibberellin concentrations control treatment (0mg/litre) recorded significantly 14.75$^{o}$brix) the highest TSS whilst 300mg/litre recorded the least (10.33$^{o}$brix) TSS.

The combination that recorded the highest TSS was Kapoho variety with no gibberellins treatment (control) whilst the least combination was sunrise and kapoho with 300mg/litre respectively.

Table 4. 11: Effect of papaya varieties and growth regulator (Gibberellins) on TSS

| Papaya variety | Concentration of Gibberellins (mg/litre) | | | | Mean |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | |
| **Sunrise** | 13.00[b] | 12.50[bc] | 11.50[cd] | 10.33[d] | **11.83**[b] |
| **Kapoho** | 16.50[a] | 12.83[b] | 12.00[bc] | 10.33[d] | **12.92**[a] |
| **Mean** | **14.75**[a] | **12.67**[b] | **11.75**[c] | **10.33**[d] | |
| **CV (%) 4.29** | | | | | |

*****Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

### 4.6.15 Effect of Papaya Varieties on Total Titratable Acidity

The effect of varieties of papaya fruit on TTA was not statistically significant ($p = 0.38$).

### 4.6.16 Effect of Concentrations of Gibberellins onTotal Titratable Acidity

The effect of gibberellins concentration on TTA is presented in Table 4.12. Significant differences ($p = 0.01$) were observed among the various concentrations. The control treatment (0mg/litre) recorded significantly the highest TTA of 0.50. Significant differences were also observed among the treatments, 100mg/litre and 200mg/litre and 300mg/litre with TTA values 0.40, 0.33, and 0.22 respectively. Concentration of 300mg/litre recorded significantly the least TTA of 0.22.

Table 4. 12: Effect of concentrations on TTA

| Concentrations (mg/litre) | TTA |
|---|---|
| 0 | 0.22[d] |
| 100 | 0.33[c] |
| 200 | 0.40[b] |
| 300 | 0.50[a] |
| Mean | **0.36** |

C. V. (%) 9.40

*****Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

### 4.6.17 Effect of Papaya Varieties and Gibberellins Concentrations on Total Titratable Acidity

There were no significant ($p$ = 0.28) interaction between papaya varieties and gibberellins concentrations.

### 4.6.18 Effect of Papaya Varieties on Sugar: Acid Ratio

Significant difference ($p$ = 0.18) was not observed between the papaya varieties for the sugar: acid ratio.

### 4.6.19 Effect of Concentrations of Gibberellins on Sugar: Acid Ratio

The effect of gibberellins concentration on TSS/TTA on pH is presented in table 4.13.

Significant differences ($p$=0.01) were observed among the various concentrations. No significant difference was observed between the control (0.53) and the fruits applied with $GA_3$ Concentration of 100mg/litre (0.45). Also, fruits dipped in 200mg/litre(0.37) was statistically similar to 100mg/litre and 300mg/litrer, respectively. However, the 300mg/litre recorded the least TTS/TTA (0.31) but statistically different from the control.

Table 4.13: Effect of concentrations on TTA/TSS

| Concentrations (mg/litre) | TTA/TSS |
|---|---|
| 0 | 0.53[a] |
| 100 | 0.45[ad] |
| 200 | 0.37[dc] |
| 300 | 0.31[c] |
| **Mean** | **0.42** |
| **C. V. (%) 12.6** | |

***Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

**4.6.20 Effect of Papaya Varieties and Gibberellins Concentrations on Sugar: Acid Ratio**

There were no significant ($p = 0.85$) interaction between papaya varieties and gibberellins concentrations.

**4.6.21 Effect of Gibberellins on Sensory Scores of Papaya Fruits**

Significant differences ($p = 0.01$) were observed among the various concentrations for the pulp colour. Pulp colour ranged from 3.33 to 4.50. Fruits applied with gibberellins concentration of 300mg/litre recorded the highest colour of 4.50 but was statistically similar to the control which recorded a value of 4.33. Fruits dipped in concentrations of 100mg/litre and 200mg/litre each recorded a value of 3.33. Papaya varieties did not show any significant difference ($p = 0.33$). The interaction effect was also not significant ($p = 0.07$).

Different concentrations for the aroma showed significant differences ($p = 0.01$).Sensory scores for aroma ranged from 2.50 to 4.83. The control with 0mg/litre scored the highest aroma of 4.83. However, the control was similar to the fruits applied with gibberellin concentrations of 300mg/litre which scored 4.50. Papaya fruits with concentrations of 100mg/litre and 200mg/litre each scored values of 2.50 and 3.50 respectively. Papaya varieties did not show any significant difference ($p$ = 0.03). The interaction effect was also not significant ($p$ = 0.10).

Significant differences ($p$ = 0.01) were noticed among the various concentrations for taste. The taste recorded values staring from 3.17 to 4.77. Fruits in Gibberellins concentrations of 300mg/litre and the control of 0mg/litre both scored the highest value of 4.77. Fruits with concentrations of 100mg/litre and 200mg/litre each recorded the values of 3.17 and 3.77 respectively.

Papaya varieties did not show any significant difference ($p$ = 0.71). The interaction effect was also not significant ($p$ = 0.10).

Significant differences ($p$ = 0.01) were observed among the various concentrations for mouth feel. Mouth feel recorded values ranging from 2.83 to 4.77. The control with 0mg/litre scored the highest aroma of 4.77. The control however, was similar to the fruits with gibberellin concentrations of 300mg/litre which scored 4.17. Papaya varieties did not show any statistical difference ($p$ = 0.13). The interaction effect was also not significant ($p$ = 0.48).

Significant differences ($p$ = 0.01) were noticed among the various concentrations for general acceptability. The papaya fruit acceptance recorded values staring from 2.83 to 4.67. The control with 0mg/litre scored the highest aroma of 4.67.

The control was similar to the fruits in gibberellin concentrations of 300mg/litre which scored 4.17. Papaya varieties did not show any statistical difference ($p$ = 0.02). The interaction effect was also not significant ($p$ = 0.82).

Table 4.14: Effect of gibberellins concentrations on sensory attributes of papaya fruits

| **CONCENTRATIONS (Mg/litre)** | **PULP COLOUR** | **AROMA** | **TASTE** | **MOUTH FEEL** | **ACCEPT.** |
|---|---|---|---|---|---|
| 0 | $4.33^{a}$ | $4.83^{a}$ | $4.77^{a}$ | $4.77^{a}$ | $4.67^{a}$ |
| 100 | $3.33^{b}$ | $2.50^{c}$ | $3.17^{b}$ | $2.83^{b}$ | $2.83^{b}$ |
| 200 | $3.33^{b}$ | $3.50^{b}$ | $3.77^{b}$ | $3.77^{ab}$ | $3.83^{ab}$ |
| 300 | $4.50^{a}$ | $4.50^{a}$ | $4.77^{a}$ | $4.17^{a}$ | $4.17^{a}$ |
| **MEANS** | **3.88** | **3.83** | **4.04** | **3.83** | **3.88** |
| **C.V. (%)** | **13.94** | **13.04** | **13.36** | **19.92** | **18.25** |

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

### 4.6.22 Effect of Papaya Varieties on Colour from Day Two to Day Eleven

Table 4.15 presents the effect of sunrise and kapoho varieties on colour. Significant differences were not observed on days 2, 4, 5, 6, 8, 9, 10 and 11 for colour. However, significant differences occurred for days 3 and 7.

Table 4.15: Effect of papaya varieties on colour

| **Variety** | | | | **Days** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Sunrise | 1.5[a] | 2.8[a] | 3.1[a] | 4.2[a] | 4.5[a] | 2.8[b] | 3.5[a] | 3.6[a] | 4.3[a] | 5.4[a] |
| Kapoho | 1.3[a] | 2.0[b] | 3.0[a] | 3.5[a] | 3.9[a] | 4.5[a] | 3.8[a] | 3.7[a] | 4.5[a] | 5.7[a] |
| **C. V. (%)** | 19.35 | 12.46 | 21.45 | 20.79 | 16.89 | 21.63 | 30.50 | 32.47 | 27.96 | 24.98 |

Scale: 1: Green skin without yellow stripe 2: Green skin with light yellow stripe

3: Green with well-defined yellow stripe4: One or more yellow stripe

5: Fairly orange – coloured skin 6: Clearly orange – coloured skin with light green

areas.7: Characteristic orange – coloured skin 8: Fruit colour similar to 7 but more

Intense.

### 4.6.23 Effect of Concentrations (Gibberellins) on Colour from Day Two to Day Eleven

Table 4.16 showed effect of gibberellin concentrations on colour. Significant differences were observed among the various concentrations from day 2 to day 11. At 0mg/litre (control) fruits for both varieties attained their maximum colour on day 7 showing a more intensive characteristic orange coloured skin.

Table 4.16: Effect of gibberellins concentrations on colour

| Concentrations Mg/litre | Days 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | $2.33^{a}$ | $4.33^{a}$ | $4.42^{a}$ | $6.50^{a}$ | $7.47^{a}$ | $7.50^{a}$ | $7.69^{a}$ | $7.81^{a}$ | $7.83^{a}$ | $8.00^{a}$ |
| 100 | $1.08^{b}$ | $2.08^{b}$ | $3.00^{b}$ | $3.08^{b}$ | $4.00^{b}$ | $5.25^{a}$ | $6.58^{ab}$ | $6.88^{ab}$ | $6.75^{a}$ | $7.46^{a}$ |
| 200 | $1.08^{b}$ | $2.25^{b}$ | $2.83^{b}$ | $3.08^{b}$ | $3.75^{b}$ | $4.30^{a}$ | $5.41^{b}$ | $5.80^{b}$ | $5.75^{a}$ | $6.27^{a}$ |
| 300 | $1.08^{b}$ | $1.17^{c}$ | $2.09^{b}$ | $2.67^{b}$ | $2.73^{c}$ | $3.00^{b}$ | $3.00^{c}$ | $3.30^{b}$ | $4.00^{b}$ | $4.70^{b}$ |
| **C. V. (%)** | 19.35 | 12.46 | 21.45 | 20.79 | 16.89 | 21.63 | 30.50 | 32.47 | 27.96 | 24.98 |

Scale: 1: Green skin without yellow stripe 2: Green skin with light yellow stripe

3: Green with well-defined yellow stripe 4: One or more yellow stripe

5: Fairly orange – coloured skin 6: Clearly orange – coloured skin with light green areas. 7: Characteristic orange – coloured skin 8: Fruit colour similar to 7 but more intense.

### 4.6.24 Effect of Papaya Varieties and Growth Regulator (Gibberellins) on Colour – Day 3

The combined effect of varieties and growth regulator was statistically significant ($p$ = 0.01) for colour on the third day of storage. Fruits of Sunrise variety of papaya had a mean colour value of 3, whilst kapoho recorded a mean colour of 2. For the concentrations, the control recorded the highest mean colour value of 4, whilst 300mg/litre concentration recorded a mean colour value of 1.

Fruits of Sunrise variety not applied with the gibberellins concentrations recorded a colour value of 5, which is significantly different from kapoho variety without any application with $GA_3$concentration recording a value of 4.

Table 4.17: Effect of papaya varieties and growth regulator (Gibberellins) on colour – Day 3

| Papaya variety | Concentration of Gibberellins (mg/litre) | | | | Mean |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | |
| **Sunrise** | $5.00^{a}$ | $2.17^{c}$ | $3.00^{b}$ | $1.33^{de}$ | $\mathbf{2.88}^{a}$ |
| **Kapoho** | $3.67^{b}$ | $2.00^{cd}$ | $1.50^{cde}$ | $1.00^{e}$ | $\mathbf{2.04}^{b}$ |
| **Mean** | $\mathbf{4.33}^{a}$ | $\mathbf{2.08}^{b}$ | $\mathbf{2.25}^{b}$ | $\mathbf{1.17}^{c}$ | |
| **CV (%) 12.46** | | | | | |

*****Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Scale: 1: Green skin without yellow stripe 2: Green skin with light yellow stripe

3: Green with well-defined yellow stripe 4: One or more yellow stripe

5: Fairly orange – coloured skin 6: Clearly orange – coloured skin with light green areas. 7: Characteristic orange – coloured skin 8: Fruit colour similar to 7 but more intense.

# CHAPTER FIVE

# 5.0 DISCUSSION

## 5.1 GENDER OF PAPAYA FRUIT PRODUCERS

From the results, the higher percentage representing males in the study area could be attributed to the fact that traditionally males have access to land than females because of marriage.

## 5.2 AGE DISTRIBUTION OF PAPAYA FRUIT PRODUCERS

The results indicated that the youth constituted a larger population in the study area. Youth are energetic and vibrant, therefore can use their energy to provide labour in the cultivation of the crop; hence this is good for the papaya industry.

## 5.3 LEVEL OF EDUCATION OF RESPONDENTS

Majority of the respondents have some form of education from Primary to Tertiary. Education enhances people adoption rate and the willingness to accept new innovations. The results are in agreement with Sabo (2006) who asserted that education is generally pivoted as an important variable that promotes the adoption of new innovations. In a related development, Adams (1982) also asserted that education has the propensity of promoting understanding in post-harvest technology.

## 5.4 PAPAYA VARIETIES GROWN BY FARMERS

Majority of the farmers cultivating Kapoho variety of papaya in the study area could be attributed to the fact that Kapoho is highly demanded by consumers because of its shelf-life. This affirms the assertion by Burden *et al.* (1993) that cultivar has an effect on shelf-life.

## 5.5 SHELF-LIFE OF PAPAYA FRUITS AFTER HARVEST

The short shelf-life of papaya fruits after harvest could be attributed to high respiration rate which leads to cell wall degradation.

## 5.6 MAJOR PROBLEMS ENCOUNTERED DURING PAPAYA PRODUCTION

From the results the major problem encountered during papaya production was shorter shelf life of papaya fruit after harvest. Shorter shelf life of fruits could be due to high temperatures accompanied by respiration. This is in agreement with Salveit (2004), who asserted that high temperature increases the biological reactions in fruits such as metabolism and respiration. During respiration, the biochemical activities of the fruits increase and thus causing them to lose more moisture.

## 5.7 LABORATORY ANALYSIS

### 5.7.1 Papaya Varieties and Growth Regulator (Gibberellins) on Percentage (%) Moisture Content

The highest percentage moisture content was recorded by Kapoho variety treated with 300mg/litre of gibberellins. This could be due to varietal differences. Higher percentage moisture content of fruits extends their shelf life. Burdern *et al.* (1993) similarly observed that cultivar has significant effect on shelf-life, quality, moisture loss and ripening of papaya fruits. Papaya fruits applied with 300mg/litre had the highest mean moisture content. This could be attributed to the fact the $GA_3$ slowed down respiration rate. Lu and Lu (1992), reported that gibberellins inhibited respiration rate in apple.

**5.7.2 Papaya Varieties and Growth Regulator (gibberellins) on Weight (g).**

Papaya fruits treated with $GA_3$ at 300mg/litre recorded the lowest mean weight loss after storage. The reduction in the weight loss could be attributed to the effect of the $GA_3$ treatment, which served as a barrier against oxygen, carbon dioxide and moisture loss,hence lowering respiration and water loss. Lu and Lu (1992) reported that gibberellins ($GA_3$) application inhibited respiration rate in apple.

**5.7.3 Firmness (N) of Papaya Fruits**

Fruits with Gibberellins concentration of 300mg/litre recorded the most firmness after the storage period followed by fruits in 100mg/lirtre and 200mg/litre concentrations. The highest firmness recorded in fruits at 300mg/litre could be attributed to slow cell wall degradation and respiration rate. This is in line with the assertion by Lu and Lu (1992), who reported that gibberellins application inhibited respiration rate in apple. Similarly, Desai and Kotecta(1995) reported that an increase in firmness, starch, cellulose, and hemicellulose content was observed when papaya fruits were treated with $GA_3$.

**5.7.4 Papaya Variety on Colour**

Peel colour of papaya fruits is one of the major visual characteristics. There was continuous change of colour in papaya varieties from green to yellow over the storage period. Papaya varieties remained the same in colour during the storage period.

**5.7.5 Gibberellins ($GA_3$) Concentrations on Colour**

$GA_3$ concentration of 0mg /litre, and two varieties of papaya fruits indicated quicker change in colour followed by fruits in concentrations of 100mg/litre and 200mg/litre respectively. The control fruits attained their maximum colour after 6 days of storage for both varieties. The papaya fruits treated with 100mg/litre and 200mg/litre concentrations of gibberellins showed slow colour change during the storage period. However, colour change was much slower in $GA_3$ concentration of fruits at 300mg/litre until day 15 with fairly orange-coloured skin. The delay in colour change may be due to decrease in chlorophylase activity (Lu and Lu, 1992) in the papaya fruits at 300mg/litre of $GA_3$ concentration. Kader, (1992) reported similar results for mango.

**5.7.6 Varieties on Shelf-life**

From the results, it was observed that kapoho took a more mean number of 11 days to ripen than sunrise. Which could be attributed to varietal differences This affirms the assertion by Burden *et al.* (1993) that cultivar has an effect on shelf-life.

**5.7.7 Gibberellins Concentration on Shelf-life of Papaya Fruits**

Increasing the gibberellins concentrations increased the mean number of days to ripening.The highest mean number of days (15) was recorded when the maximum concentration of 300mg/litre was applied. The lowest mean number of days (6) was recorded when no $GA_3$ (0mg/litre) was applied. This showed that ripening delayed in 300mg/litre of $GA_3$ treated papaya fruits and exhibited better shelf-life as compared to 0mg/litre, 100mg/litre, and 200mg/litre respectively. This could be attributed to slow chlorophylase activity. This result is in line with the results of other researchers who reported that post-harvest dipping of papaya fruits in aqueous solutions of $GA_3$ retarded chlorophyll degradation and decline in the activities of amylase and peroxidase (Kader, 1992). Mehta *et al*. (1986) also reported that $GA_3$ application on fruits significantly suppressed the succinate activities of malate dehydrogenase in papaya fruits during post-harvest ripening thus enhancing shelf-life.

### 5.7.8 Sensory Attributes of Papaya Fruits

Generally, the $GA_3$ concentrations on sensory attributes of papaya fruits were highly accepted by the 10 panelists. $GA_3$ concentration of 300mg/litre had the highest scored values by the panelists followed by the control, 100mg/litre and 200mg/litre after the storage period. Sensory evaluation of papaya fruits treated with $GA_3$ concentration of 300mg/litre therefore, exhibited supremacy of eating quality after 15 days of storage. This implies that $GA_3$ concentration of 300mg/litre can be used to extend shelf-life for consumption without any effect on eating qualities of papaya fruits.

Mehta *et al.* (1986) reported that post-harvest treatment of papaya fruits were found to extend shelf-life without any adverse effect on palatability. In a related development, other researchers reported that post-harvest treatment of $GA_3$ increased the quality of different climacteric fruits (Kandunga *et al.*, 2013).

### 5.7.9 Gibberellins Concentration on pH

From the results, papaya fruits with 0mg/litre had the highest pH value followed by $GA_3$ concentrations of 100mg/litre, and 200mg/litre after the storage period. The highest pH value attained by the control could be due to high respiration rate. This is in line with other researchers who reported that the use of acid as respiratory substrates might increase at a higher temperature (Wills *et al*., 1989). However, $GA_3$ concentration of 300mg/litre maintained low pH after the storage period and this could be attributed to the effect of $GA_3$ treatment on the fruits which lead to slow respiration. Vendrell and Palomer (1997) asserted that postharvest dipping of papaya fruits into aqueous solution of gibberellins retarded chlorophyll degradation and decline in the activities of amylase and peroxidase. However, papaya varieties and gibberellins concentration did not have effect on pH.

### 5.7.10 TSS ($^0$brix)

The maximum TSS was recorded in the control followed by $GA_3$ concentrations of 100mg/litre, and 200gmg/litre respectively. The least TSS was however, recorded in 300mg/litre of $GA_3$ concentration.

Thus, the $GA_3$ concentration of300mg/litre might have delayed the accumulation of TSS during the storage period hence accounting for slow ripening. This agrees with Ahmed and Tingwa (1995) that $GA_3$ decreased sugar accumulation, TSS and sugar/acid ratio in banana.

### 5.7.11 TTA (Total Titratable Acidity)

The control treatment recorded significantly the least TTA value followed by fruits in 100mg/litre, and 200mg/litre concentrtions respectively. However, fruits applied with 300mg/litre recorded the highest TTA. The highest value recorded in TTA could be due to the slow breakdown of organic acids as they respire or converted to sugar (Wills *et al.*, 1989).

### 5.7.12 TTA/TSS (Sugar: Acid) ratio

The control fruits recorded the highest TTA followed by fruits in 100mg/litre and 200mg. However, fruits in 300mg/litre recorded the least TTS/TTA. The highest mean value obtained from the control fruits at 0mg/litre could be due to fruit acid degradation because of hydrolysis of the starch in the fruit and the accumulation of sugars (Palmer, 1971).

## CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 CONCLUSION

The effect of $GA_3$ on the postharvest life and quality of papaya fruit varieties under ambient storage conditions were studied and the following conclusions could be drawn from the results.

1. Kapoho stored longer than sunrise. Kapoho stored for a mean of 11 days while Sunrise stored for 10 days.

2. Gibberellins ($GA_3$) delayed ripening of papaya fruits and were able to increase the shelf-life of the fruits from a mean of 6 days to 15 days. Increasing $GA_3$ concentration to 300mg/litre caused more delay to ripening of the fruits without any adverse effect on fruit quality.

3. Sensory evaluation of papaya fruits after the storage period was highly accepted by the panelists.

### 6.2 RECOMMENDATIONS

Based on the outcome of the study, the following recommendations are made:

- Further research should be carried out by selecting papaya fruits from plants that follower at the same time.
- Future research should be conducted on the chemical residues on papaya fruits after $GA_3$ application.
- Further work could be carried out on other varieties of papaya fruits.

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## APPENDICES

## APPENDIX A: QUESTIONNAIRE

1. Name of farmer……………………………………sex…..........Adress/phone number…………………..

2. What is your marital status? a. married [ ] b. single [ ] c. divorce [ ] d. separated [

3. What is your level of education?..........................................................................

4. How many acres of papaya do you produce a year?...............................................

5. How many years have been in papaya production?.............................................

6. How many varieties of papaya are available?.......................................................

7. Which of the varieties of papaya do you use in cultivation?.........................................

8. Give reasons why you use that variety for production?..............................................

9. Where do you keep these varieties before planting?.................................................

10. From which source do you obtain these planting materials?.................................

11. How many days do your papaya plants take to bear fruits?.................................

12. What are the maturity indices you consider before harvesting?..............................

13 At what stage of ripening do you harvest the fruits? a. half ripe [ ] Fully ripe [ ]

14. Give reasons for harvesting at the stage harvested…………………………………

15. What time of the day do you harvest your papaya fruits?..............................

16. Do you pre-cool papaya fruits after harvest? a. Yes [ ] b. No [ ]

17. If yes, how?..........................................................................................................

18. Do you encounter post-harvest losses after harvesting papaya fruits? a. Yes [ ] b. No [ ]

19. If yes, enumerate the causes of these losses…………………………………………………........

20. Where do you keep the fruits immediately after harvest?.....................................

21 . Do you treat the papaya fruits with chemicals before distribution? Yes [ ] No [ ]

22. If yes, why?..............................................................................................................

23. How long do you store papaya fruits before sale?.................................................

24. How long do papaya fruits take before senescence?.................................................

25. What are the major problems associated with papaya production?.......................

## APPENDIX B: ANALYSIS OF VARIANCE (ANOVA) TABLES

**Appendix A1: Analysis of variance Table for percentage moisture content**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 8.7604 | 8.76042 | 105.13 | 0.0000 |
| Gibberell | 3 | 29.6979 | 9.89931 | 118.79 | 0.0000 |
| Pawpaw*Gibberell | 3 | 7.1979 | 2.39931 | 28.79 | 0.0000 |
| Error | 16 | 1.3333 | 0.08333 | | |
| Total | 23 | 46.9896 | | | |

Grand Mean 86.729 CV 0.33

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = 0.34, Gibberellins = 0.49, Papaya*Gibberellins = 0.69.

**Appendix A2: Analysis of variance Table for Weight**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 4.38 | 4.378 | 0.11 | 0.7486 |
| Gibberell | 3 | 2625.10 | 875.032 | 21.24 | 0.0000 |
| Pawpaw*Gibberell | 3 | 20.80 | 6.932 | 0.17 | 0.9162 |
| Error | 16 | 659.03 | 41.189 | | |
| Total | 23 | 3309.30 | | | |

Grand Mean 27.037 CV 23.74

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 10.82, Papaya*Gibberellins = NS.

**Appendix A3: Analysis of Variance Table for Aroma**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.3750 | 0.37500 | 1.29 | 0.2735 |
| Gibberell | 3 | 7.1250 | 2.37500 | 8.14 | 0.0016 |
| Pawpaw*Gibberell | 3 | 2.4583 | 0.81944 | 2.81 | 0.0729 |
| Error | 16 | 4.6667 | 0.29167 | | |
| Total | 23 | 14.6250 | | | |

Grand Mean 3.8750 CV 13.94

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins =0.91, Papaya*Gibberellins =NS.

**Appendix A4: Analysis of Variance Table for pulp**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 1.5000 | 1.50000 | 6.00 | 0.0262 |
| Gibberell | 3 | 20.0000 | 6.66667 | 26.67 | 0.0000 |
| Pawpaw*Gibberell | 3 | 1.8333 | 0.61111 | 2.44 | 0.1016 |
| Error | 16 | 4.0000 | 0.25000 | | |
| Total | 23 | 27.3333 | | | |

Grand Mean 3.8333 CV 13.04

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins =0.84, Papaya*Gibberellins = NS.

**Appendix A5: Analysis of Variance Table for Taste**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.0417 | 0.04167 | 0.14 | 0.7104 |
| Gibberell | 3 | 10.1250 | 3.37500 | 11.57 | 0.0003 |
| Pawpaw*Gibberell | 3 | 2.1250 | 0.70833 | 2.43 | 0.1031 |
| Error | 16 | 4.6667 | 0.29167 | | |
| Total | 23 | 16.9583 | | | |

Grand Mean 4.0417 CV 13.36

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins =0.91, Papaya*Gibberellins = NS.

**Appendix A6: Analysis of Variance Table for mouth feel**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 1.5000 | 1.50000 | 2.57 | 0.1284 |
| Gibberell | 3 | 11.0000 | 3.66667 | 6.29 | 0.0051 |
| Pawpaw*Gibberell | 3 | 1.5000 | 0.50000 | 0.86 | 0.4832 |
| Error | 16 | 9.3333 | 0.58333 | | |
| Total | 23 | 23.3333 | | | |

Grand Mean 3.8333 CV 19.92

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.29, Papaya*Gibberellins = NS.

**Appendix A7: Analysis of Variance Table for acceptance**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Pawpaw | 1 | 3.3750 | 3.37500 | 6.75 | 0.0194 |
| Gibberell | 3 | 10.7917 | 3.59722 | 7.19 | 0.0028 |
| Pawpaw*Gibberell | 3 | 0.4583 | 0.15278 | 0.31 | 0.8210 |
| Error | 16 | 8.0000 | 0.50000 | | |
| Total | 23 | 22.6250 | | | |

Grand Mean 3.8750 CV 18.25

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.19, Papaya*Gibberellins = NS.

**Appendix A8: Analysis of Variance Table for Colour, Day 2**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.26042 | 0.26042 | 3.57 | 0.0770 |
| Gibberell | 3 | 7.03125 | 2.34375 | 32.14 | 0.0000 |
| Pawpaw*Gibberell | 3 | 0.53125 | 0.17708 | 2.43 | 0.1031 |
| Error | 16 | 1.16667 | 0.07292 | | |
| Total | 23 | 8.98958 | | | |

Grand Mean 1.3958 CV 19.35

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 0.45, Papaya*Gibberellins = NS.

**Appendix A9: Analysis of Variance Table for Colour, Day 3**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 4.1667 | 4.1667 | 44.44 | 0.0000 |
| Gibberell | 3 | 32.2083 | 10.7361 | 114.52 | 0.0000 |
| Pawpaw*Gibberell | 3 | 2.0833 | 0.6944 | 7.41 | 0.0025 |
| Error | 16 | 1.5000 | 0.0938 | | |
| Total | 23 | 39.9583 | | | |

Grand Mean 2.4583 CV 12.46

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = 0.37, Gibberellins = 0.57, Papaya*Gibberellins = 0.73.

**Appendix A9: Analysis of VarianceTablefor Colour, Day 4**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.0417 | 0.04167 | 0.10 | 0.7616 |

| | | | | | |
|---|---|---|---|---|---|
| Gibberell | 3 | 17.0833 | 5.69444 | 13.02 | 0.0001 |
| Pawpaw*Gibberell | 3 | 0.7083 | 0.23611 | 0.54 | 0.6619 |
| Error | 16 | 7.0000 | 0.43750 | | |
| Total | 23 | 24.8333 | | | |

Grand Mean 3.0833 CV 21.45

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.12, Papaya*Gibberellins = NS.

**Appendix A10: Analysis of VarianceTable for Colour, Day 5**

**Analysis of Variance day 5 Table for Colour**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 2.6667 | 2.6667 | 4.20 | 0.0573 |
| Gibberell | 3 | 57.5833 | 19.1944 | 30.21 | 0.0000 |
| Pawpaw*Gibberell | 3 | 1.4167 | 0.4722 | 0.74 | 0.5418 |
| Error | 16 | 10.1667 | 0.6354 | | |
| Total | 23 | 71.8333 | | | |

Grand Mean 3.8333 CV 20.79

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.34, Papaya*Gibberellins = NS.

**Appendix A11: Analysis of Variance Table for Colour, Day 6**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 2.3438 | 2.3438 | 4.59 | 0.0478 |
| Gibberell | 3 | 69.9479 | 23.3160 | 45.68 | 0.0000 |
| Pawpaw*Gibberell | 3 | 4.5313 | 1.5104 | 2.96 | 0.0638 |
| Error | 16 | 8.1667 | 0.5104 | | |
| Total | 23 | 84.9896 | | | |

Grand Mean 4.2292 CV 16.89

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.20, Papaya*Gibberellins = NS

**Appendix A12: Analysis of Variance Table for Colour, Day 7**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 18.3750 | 18.3750 | 29.90 | 0.0001 |
| Gibberell | 3 | 5.2083 | 1.7361 | 2.82 | 0.0719 |

| | | | | | |
|---|---|---|---|---|---|
| Pawpaw*Gibberell | 3 | 52.2083 | 17.4028 | 28.32 | 0.0000 |
| Error | 16 | 9.8333 | 0.6146 | | |
| Total | 23 | 85.6250 | | | |

Grand Mean 3.6250 CV 21.63

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = 0.93, Gibberellins = NS, Papaya*Gibberellins = 1.87.

**Appendix A13: Analysis of VarianceTable for Colour, Day 8**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.510 | 0.5104 | 0.42 | 0.5250 |
| Gibberell | 3 | 75.531 | 25.1771 | 20.84 | 0.0000 |
| Pawpaw*Gibberell | 3 | 6.115 | 2.0382 | 1.69 | 0.2098 |
| Error | 16 | 19.333 | 1.2083 | | |
| Total | 23 | 101.490 | | | |

Grand Mean 3.6042 CV 30.50

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.85, Papaya*Gibberellins = NS.

**Appendix A14: Analysis of VarianceTable for colour, Day 9**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.042 | 0.0417 | 0.03 | 0.8645 |
| Gibberell | 3 | 76.875 | 25.6250 | 18.50 | 0.0000 |
| Pawpaw*Gibberell | 3 | 8.042 | 2.6806 | 1.93 | 0.1647 |
| Error | 16 | 22.167 | 1.3854 | | |
| Total | 23 | 107.125 | | | |

Grand Mean 3.6250 CV 32.47

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 1.98, Papaya*Gibberellins = NS.

**Appendix A15: Analysis of VarianceTable for colour, Day 10**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.094 | 0.0937 | 0.06 | 0.8064 |
| Gibberell | 3 | 103.198 | 34.3993 | 22.77 | 0.0000 |
| Pawpaw*Gibberell | 3 | 12.531 | 4.1771 | 2.77 | 0.0758 |
| Error | 16 | 24.167 | 1.5104 | | |

| | | |
|---|---|---|
| Total | 23 | 139.990 |

Grand Mean 4.3958    CV 27.96

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 2.07, Papaya*Gibberellins = NS.

**Appendix A16: Analysis of VarianceTable for colour, day 11**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.667 | 0.6667 | 0.35 | 0.5636 |
| Gibberell | 3 | 170.875 | 56.9583 | 29.72 | 0.0000 |
| Pawpaw*Gibberell | 3 | 7.250 | 2.4167 | 1.26 | 0.3212 |
| Error | 16 | 30.667 | 1.9167 | | |
| Total | 23 | 209.458 | | | |

Grand Mean 5.5417    CV 24.98

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS, Gibberellins = 2.33, Papaya*Gibberellins = NS.

**Appendix A17: Analysis of Variance Table for Shelf**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 5.042 | 5.0417 | 10.08 | 0.0059 |
| Gibberell | 3 | 290.458 | 96.8194 | 193.64 | 0.0000 |
| Pawpaw*Gibberell | 3 | 2.458 | 0.8194 | 1.64 | 0.2200 |
| Error | 16 | 8.000 | 0.5000 | | |
| Total | 23 | 305.958 | | | |

Grand Mean 10.542    CV 6.71

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties =0.84Gibberellins = 1.19

Papaya*Gibberellins = NS

**Appendix A18: Analysis of Variance Table for pH**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.0937 | 0.09375 | 0.39 | 0.5422 |
| Gibberell | 3 | 15.7546 | 5.25153 | 21.73 | 0.0000 |
| Pawpaw*Gibberell | 3 | 0.0246 | 0.00819 | 0.03 | 0.9913 |
| Error | 16 | 3.8667 | 0.24167 | | |
| Total | 23 | 19.7396 | | | |

Grand Mean 3.5458 CV 13.86

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS Gibberellins = 0.83

Papaya*Gibberellins = NS

**Appendix 19: Analysis of Variance Table for TSS**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 7.0417 | 7.0417 | 25.04 | 0.0001 |
| Gibberell | 3 | 61.7083 | 20.5694 | 73.14 | 0.0000 |
| Pawpaw*Gibberell | 3 | 11.8750 | 3.9583 | 14.07 | 0.0001 |
| Error | 16 | 4.5000 | 0.2813 | | |
| Total | 23 | 85.1250 | | | |

Grand Mean 12.375 CV 4.29

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = 0.63 Gibberellins = 0.89

Papaya*Gibberellins = 1.26

**Appendix 20: Analysis of Variance Table for TTA**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 0.00094 | 0.00094 | 0.81 | 0.3817 |
| Gibberell | 3 | 0.26065 | 0.08688 | 75.01 | 0.0000 |
| Pawpaw*Gibberell | 3 | 0.00488 | 0.00163 | 1.40 | 0.2780 |
| Error | 16 | 0.01853 | 0.00116 | | |
| Total | 23 | 0.28500 | | | |

Grand Mean 0.3621 CV 9.40

LSD (*P*=0.01); Critical Value for ComparisonPapaya varieties = NS Gibberellins = 0.06

Papaya*Gibberellins = NS

**Appendix 21: Analysis of Variance Table for TSS/TTA**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Pawpaw | 1 | 55.21 | 55.207 | 1.98 | 0.1789 |
| Gibberell | 3 | 1704.93 | 568.310 | 20.34 | 0.0000 |
| Pawpaw*Gibberell | 3 | 22.30 | 7.434 | 0.27 | 0.8488 |
| Error | 16 | 446.99 | 27.937 | | |
| Total | 23 | 2229.43 | | | |

Grand Mean 41.867 CV 12.62

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS Gibberellins = 0.89

Papaya*Gibberellins = NS

**Appendix 22: Analysis of Variance Table for Firmness**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Pawpaw | 1 | 1.628 | 1.6276 | 1.21 | 0.2872 |
| Gibberell | 3 | 59.864 | 19.9546 | 14.86 | 0.0001 |
| Pawpaw*Gibberell | 3 | 17.830 | 5.9432 | 4.43 | 0.0190 |
| Error | 16 | 21.489 | 1.3430 | | |
| Total | 23 | 100.810 | | | |

Grand Mean 2.3804 CV 48.68

LSD (*P*=0.01); Critical Value for Comparison

Papaya varieties = NS Gibberellins = 1.95

Papaya*Gibberellins = NS